

Υ Measurements at PHENIX

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RHIC/AGS Users' Meeting

June 20, 2011

Outline

- Why do we measure Υ ?
- How do we measure Υ ?
- Cross section in pp collisions
- Nuclear Modification factors
 - R_{dA}
 - R_{AA} (ongoing)

Motivation

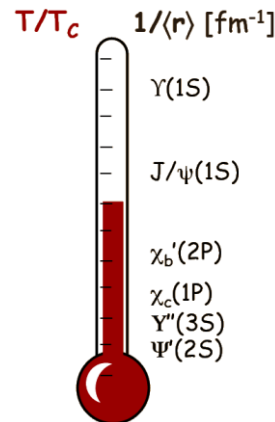
In the Quark Gluon Plasma we expect sequential screening of the resonances.



Measurement of heavy quarkonia suppression in Au+Au collisions can act as a thermometer of the QGP.

Heavy flavor resonances characterized by binding energy and radius

Mocsy & Petreczky
PRL. 99, 211602 (2007)



state	J/ψ	χ _c	ψ(2S)
Mass(GeV)	3.10	3.53	3.69
ΔE (GeV)	0.64	0.20	0.05
r ₀ (fm)	0.25	0.36	0.45

state	Y(1s)	Y(2s)	Y(3s)
Mass(GeV)	9.46	10.0	10.36
ΔE (GeV)	1.10	0.54	0.20
r ₀ (fm)	0.28	0.56	0.78

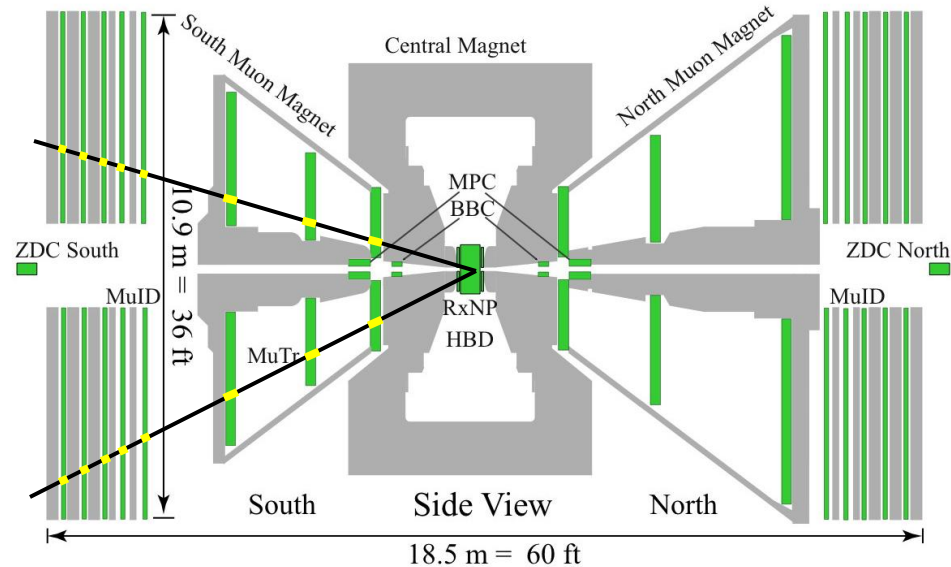
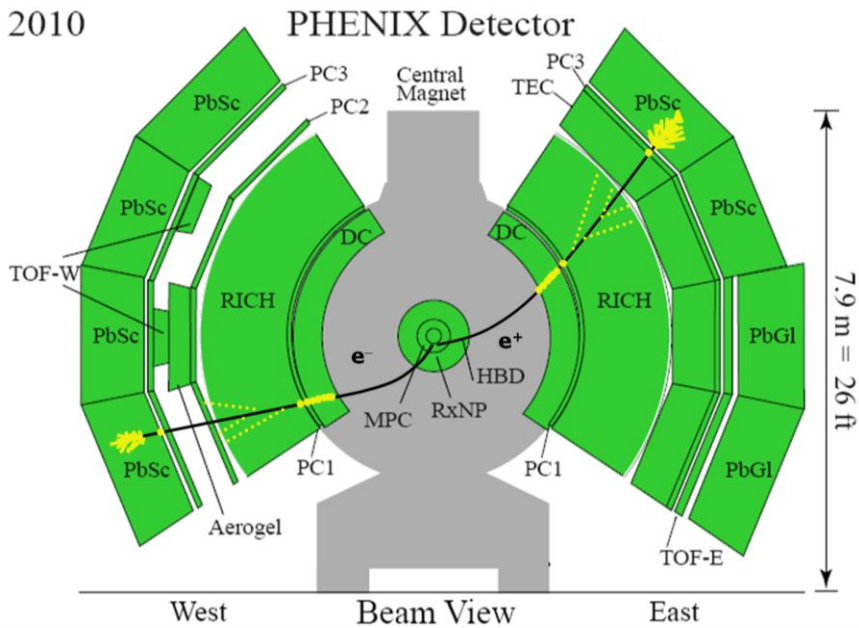
R. Arnaldi

Heavy Quarks and Quarkonia QM 2011

MEASURING Υ AT PHENIX

The PHENIX Detector

2010



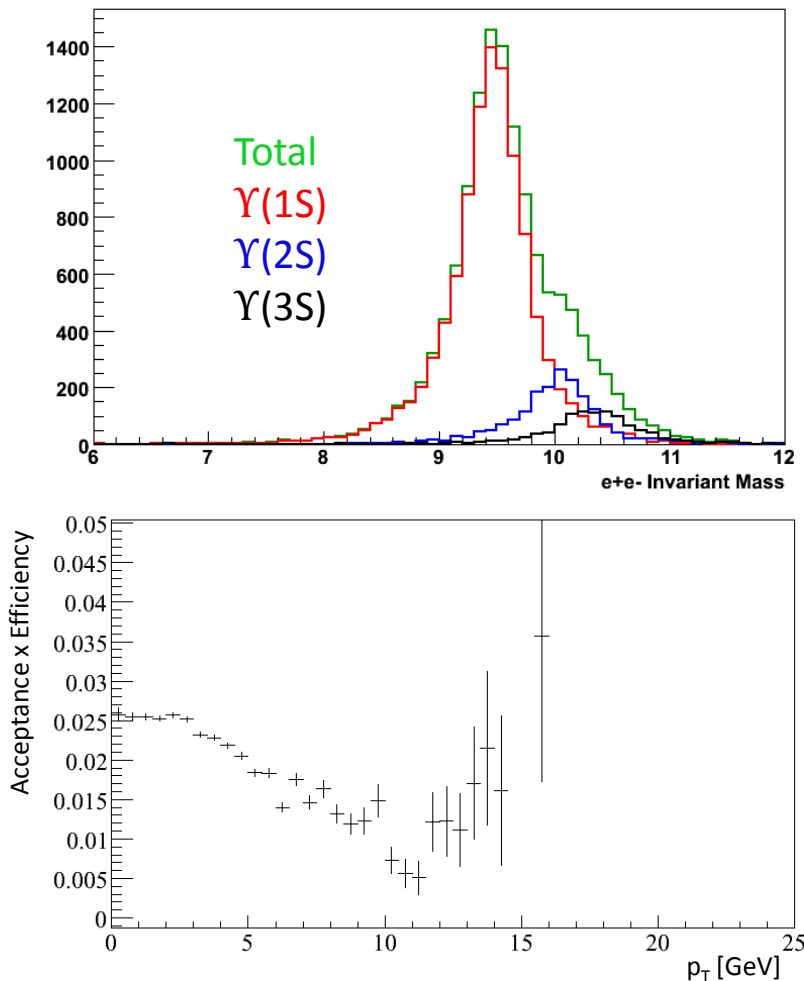
Mid rapidity: $Y \rightarrow e^+e^-$

$|\eta| < 0.35$, $\Delta\Phi = 2 \times \pi/2$, $p > 0.2$ GeV/c

Forward rapidity: $Y \rightarrow \mu^+\mu^-$

$1.2 < |\eta| < 2.2$, $\Delta\Phi = 2\pi$, $p > 2$ GeV/c

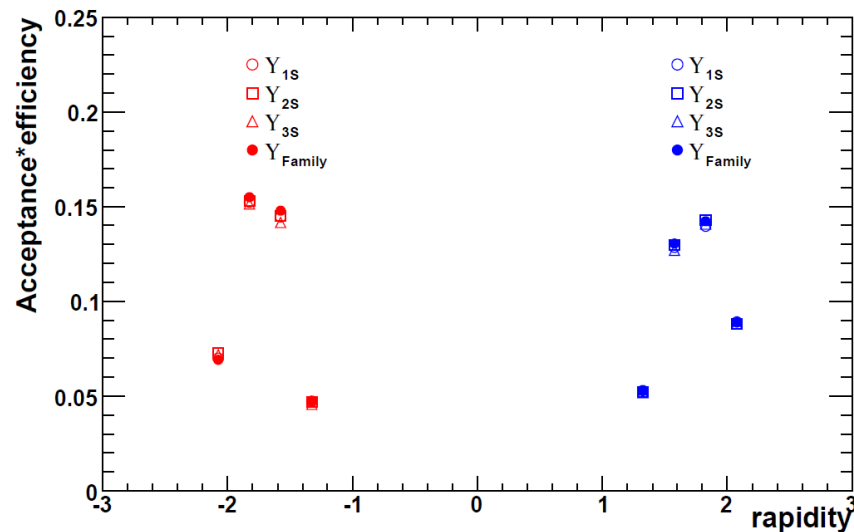
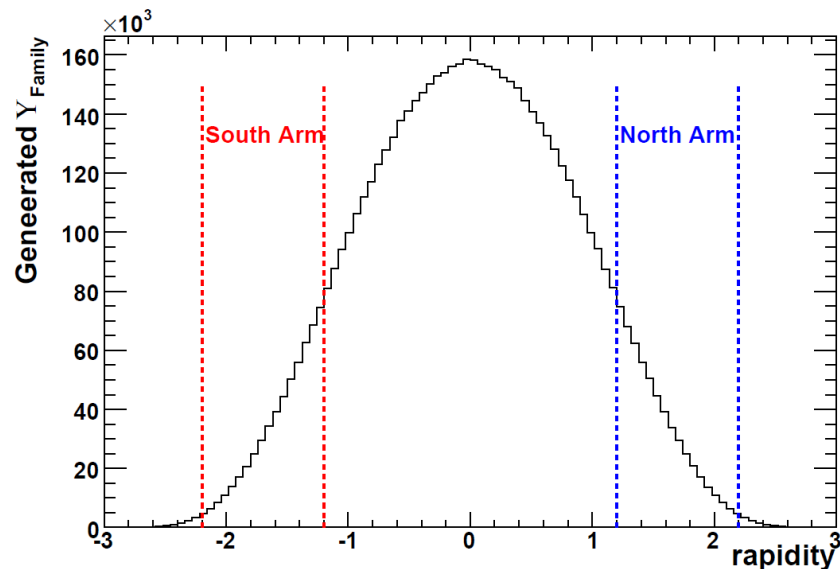
Detector Acceptance: Central Arms



Υ were simulated using PHPYTHIA (top left)
 Two models were used to simulate the p_T distribution for Υ (top right)
 Acceptance x Reconstruction efficiency is plotted as a function of momentum (left)
 The resulting integrated Acc x Eff is below

$$A \times \varepsilon_{eID}(\Upsilon) = 2.33 \pm 0.17(\text{sys. acceptance}) \pm 0.01(\text{sys. eID})\%$$

Detector Acceptance: Muon Arms



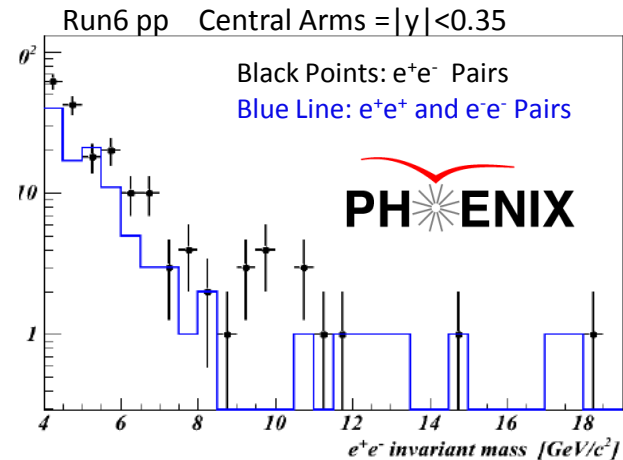
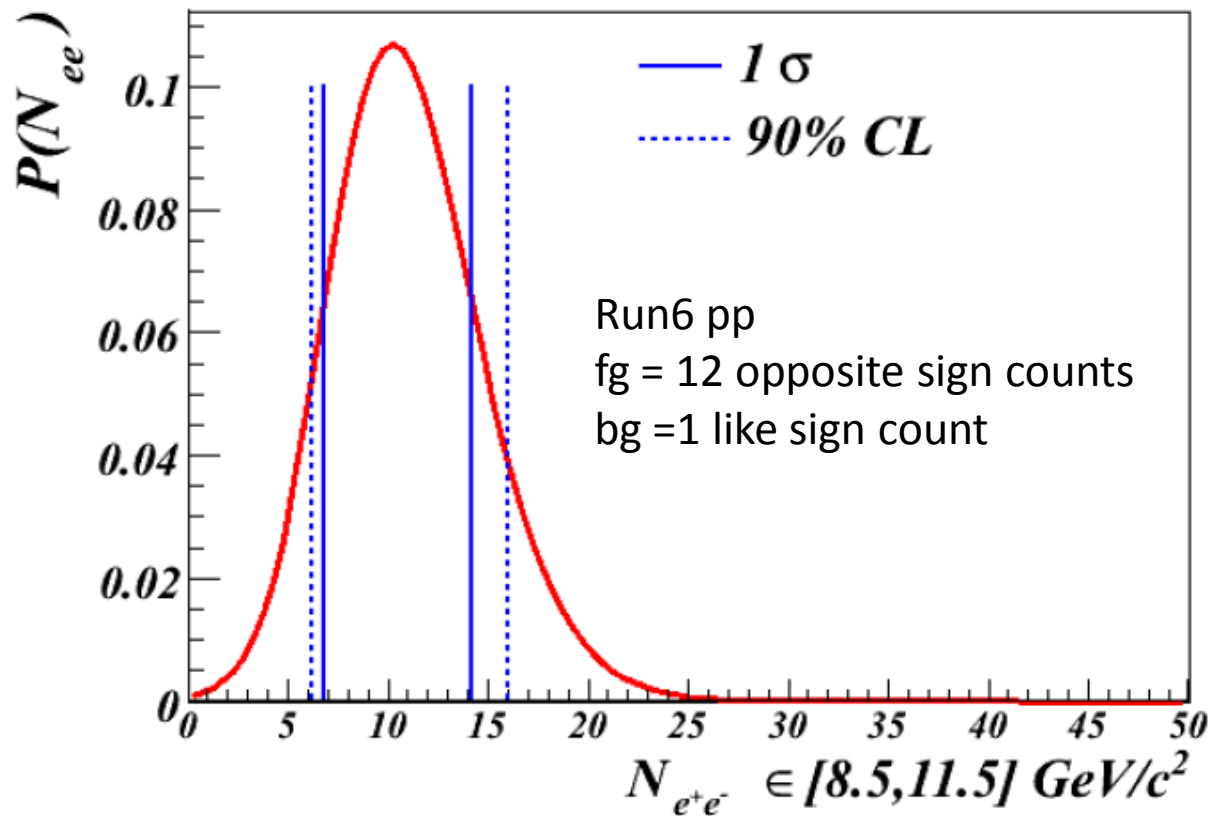
Rapidity	Thrown Y_{Family}	Reconstructed Y_{Family}	Acceptance \times Efficiency
$[-2.2, -1.2]$	566398	55521.8 ± 235.631	0.0980 ± 0.0004
$[-1.45, -1.2]$	271646	13161.6 ± 114.724	0.0485 ± 0.0004
$[-1.7, -1.45]$	170812	25732.4 ± 160.413	0.1506 ± 0.0009
$[-1.95, -1.7]$	88557	14083.8 ± 118.675	0.1590 ± 0.0013
$[-2.2, -1.95]$	35383	2546.19 ± 50.460	0.0720 ± 0.0014
$[1.2, 2.2]$	563565	53542.6 ± 231.393	0.0950 ± 0.0004
$[1.2, 1.45]$	269834	14641 ± 121.000	0.0543 ± 0.0004
$[1.45, 1.7]$	169301	22601.6 ± 150.338	0.1335 ± 0.0009
$[1.7, 1.95]$	89032	13040.1 ± 114.193	0.1465 ± 0.0013
$[1.95, 2.2]$	35398	3299.06 ± 57.438	0.0932 ± 0.0016

$Y(1S+2S+3S)$ were generated using PHPYTHIA. The rapidity distribution is shown in the top left plot.

The Acceptance \times Efficiency values are shown above and summarized to the left.

The integrated values were used for each rapidity region because of the limited statistics in the real data.

Dealing with Small Statistics



$$P(s) = \sum_{k=0}^{fg} \frac{(bg + fg - k)!}{bg!(fg - k)!} \frac{1}{2} \left(\frac{1}{2}\right)^{bg+fg-k} \frac{s^k e^{-s}}{k!}$$

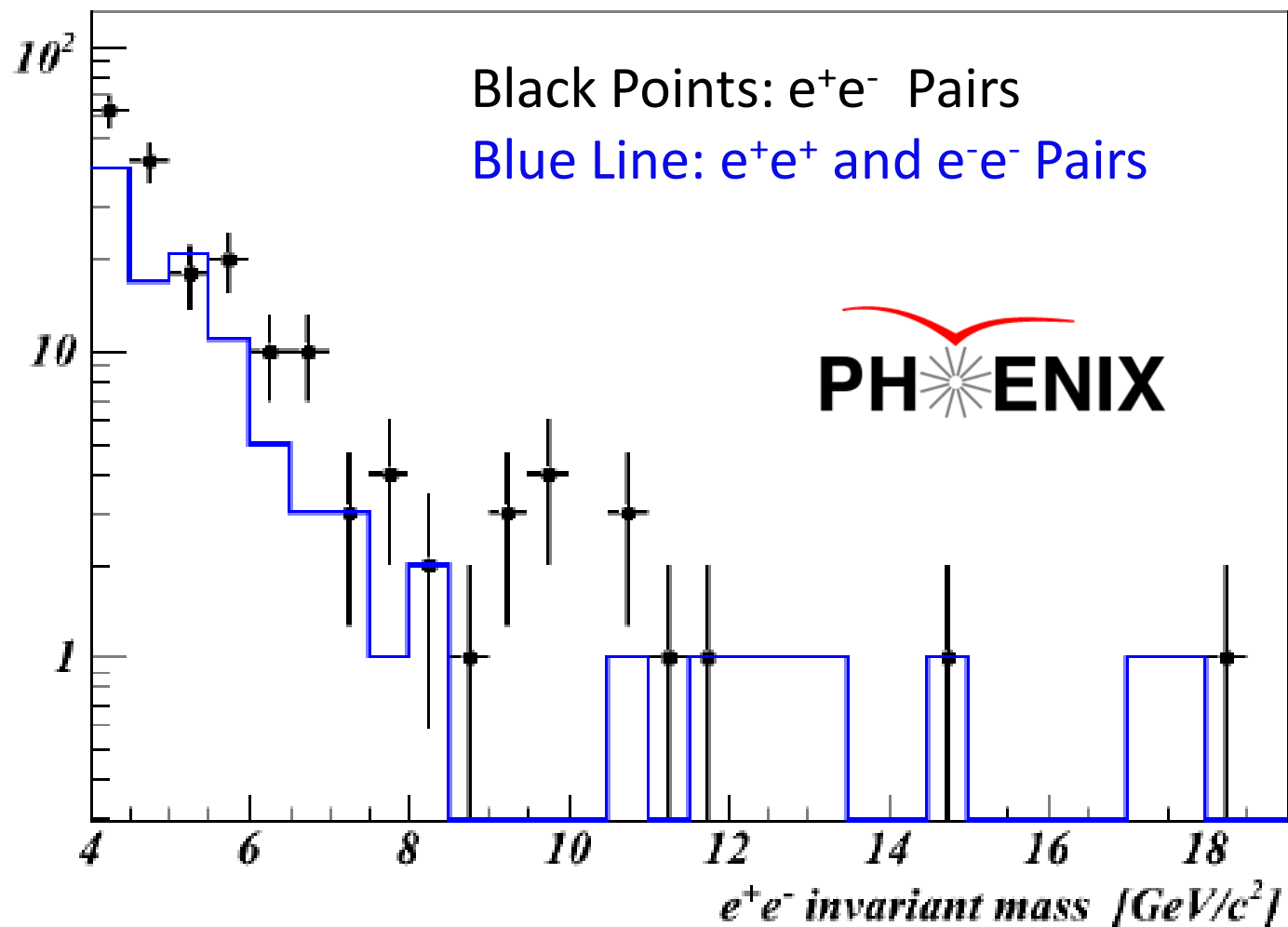
M. Tannenbaum

The Process

- Using e^+e^- and $\mu^+\mu^-$ pairs Υ candidates are reconstructed from pairs with an invariant mass from 8.5 – 11.5 GeV
- The Υ yields are estimated from these candidates after removing the background contributions
 - Combinatorial background from random e^+e^- or $\mu^+\mu^-$ pairs
 - Correlated continuum background from Drell-Yan, open bottom and open charm (semi-leptonic decays)

Combinatorial Background Subtraction

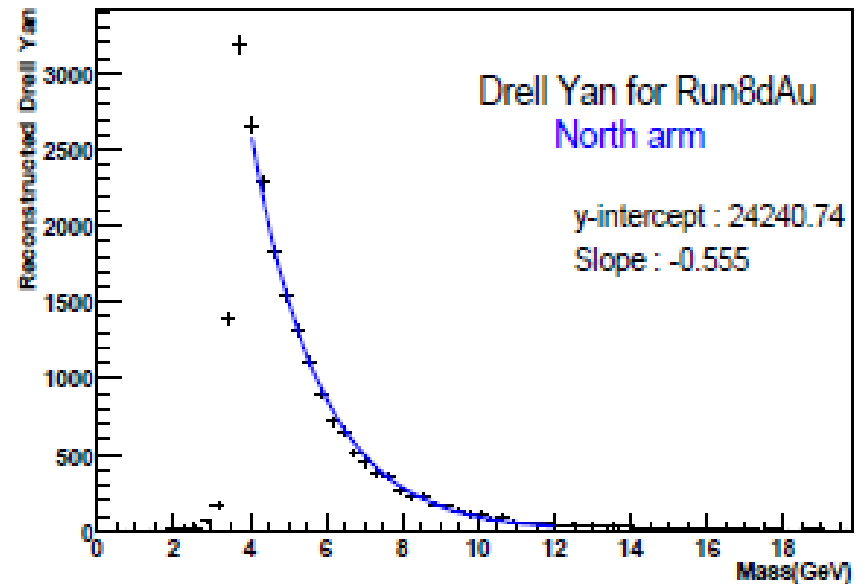
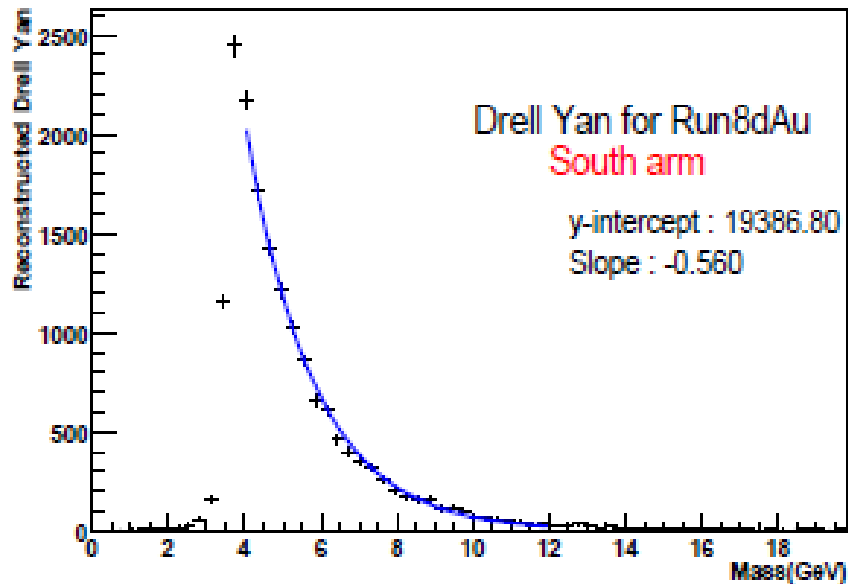
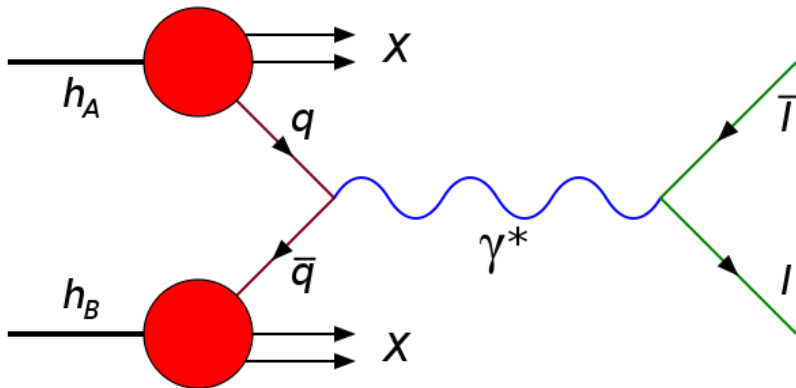
Run6 pp Central Arms = $|\eta| < 0.35$



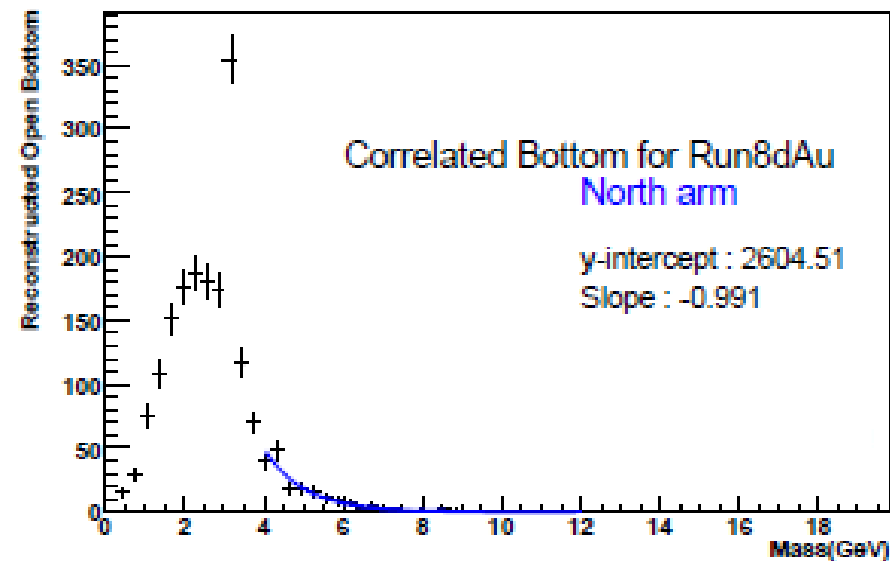
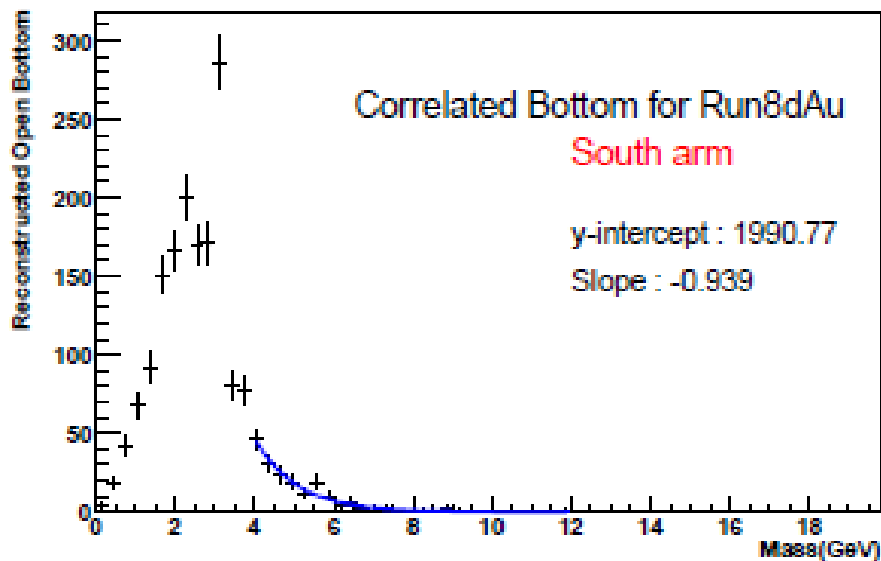
Drell Yan

PHPYTHIA Settings

Parameters	Index	Setting	Meaning
mset		11	Single W/Z production
ckin	1	3.5	set minimum mass value as 3.5 GeV
parp parp	91 31	1.5 1.1	set k_T value = 1.5 set k factor = 1.1
mstp mstp mstp	32 33 51	4 1 7	set Q_2 scale = 4 use k factor select PDF of CTEQ5L

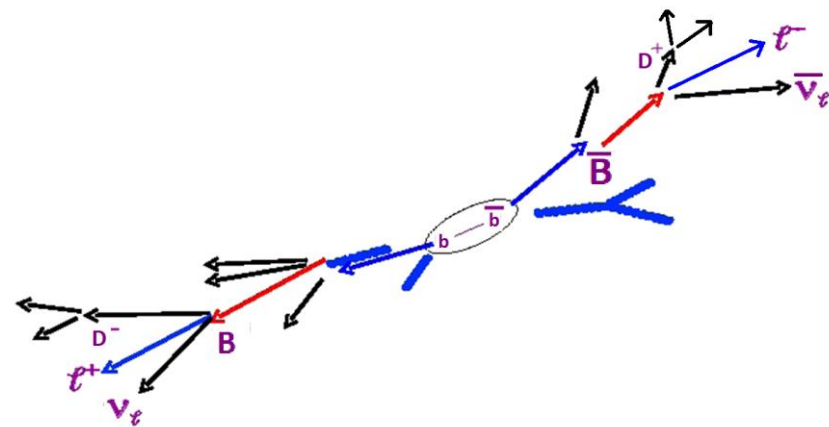


Open Bottom

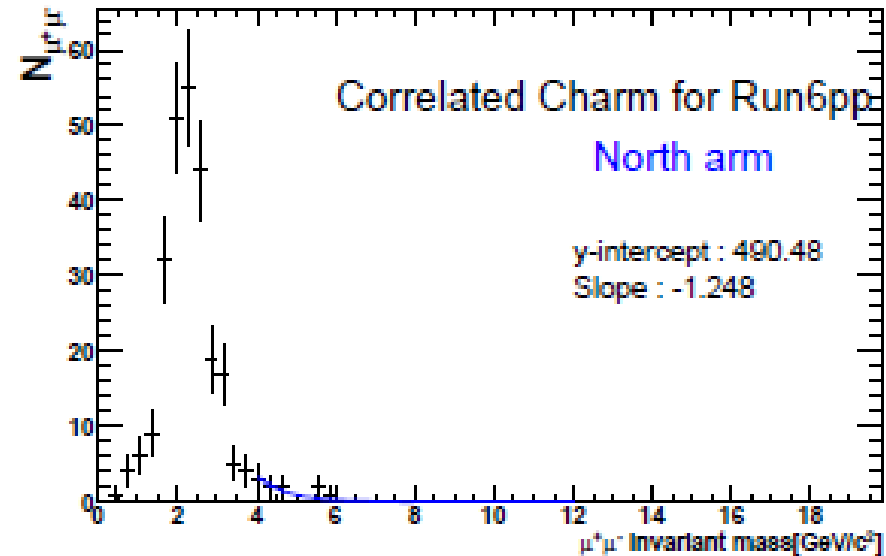
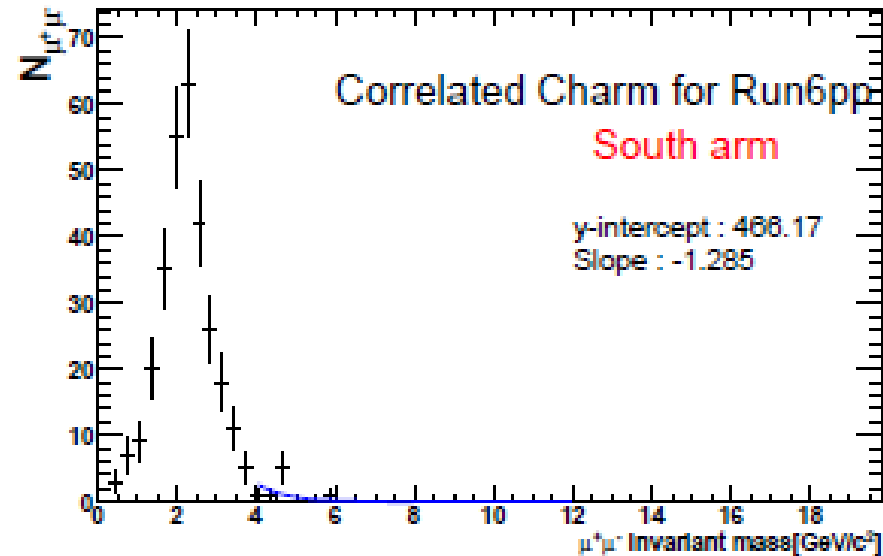


PHPYTHIA Settings

Parameters	Index1	Index2	Setting	Meaning
mse1			5	turn on bottom production of heavy flavor.
pmas	5	1	4.1	make bottom quark mass as 4.1 GeV
parp	91		1.5	set k_T value = 1.5 set k factor = 3.4 set Q_2 scale = 4 use k factor select PDF of CTEQ5L
parp	31		3.4	
mstp	32		4	
mstp	33		1	
mstp	51		7	



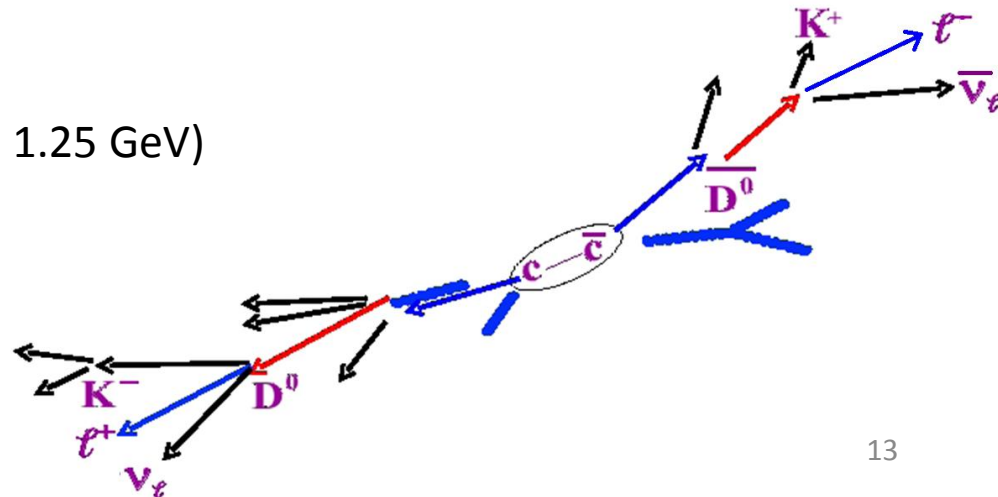
Open Charm



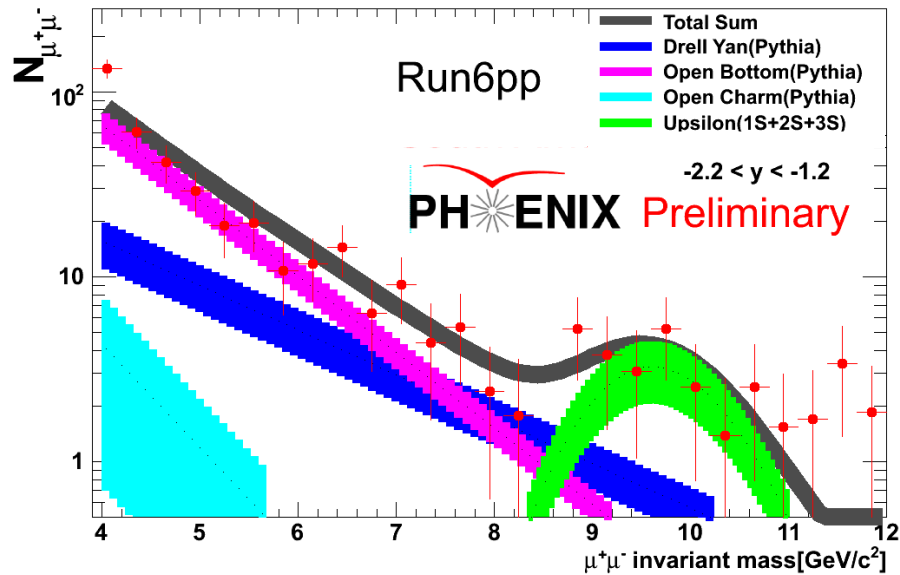
PHPYTHIA Settings

msel 4 (turns on charm production)

pmas 4 1 1.25 (sets charm quark mass to 1.25 GeV)



Invariant Mass Distributions



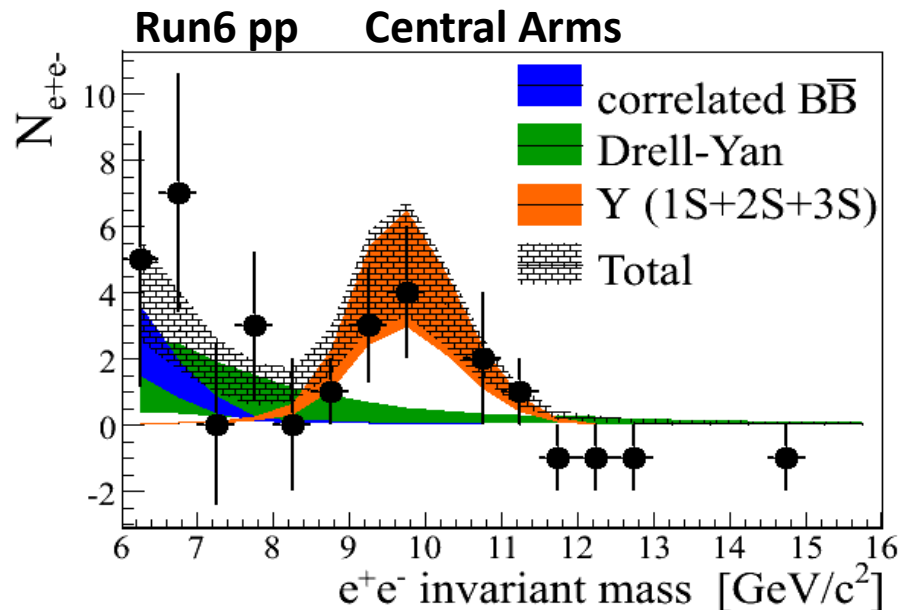
Data

Υ

Drell Yan

Open Bottom

Open Charm



Data

Υ

Drell Yan

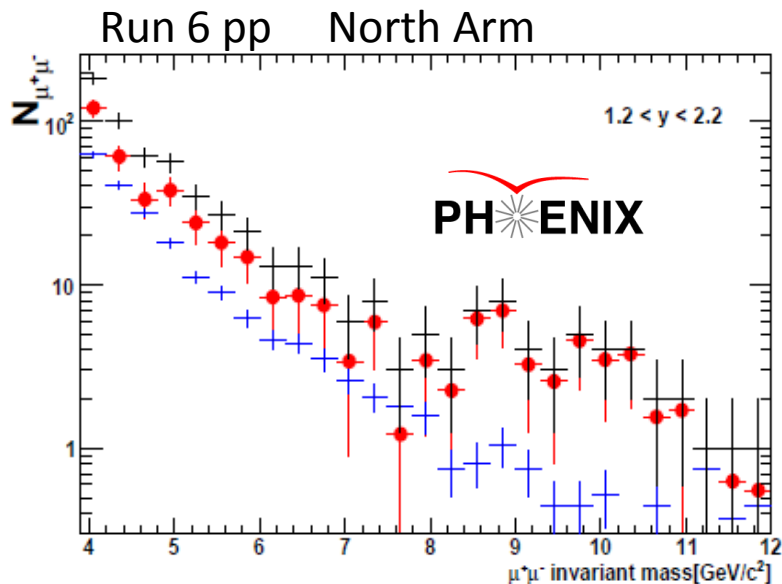
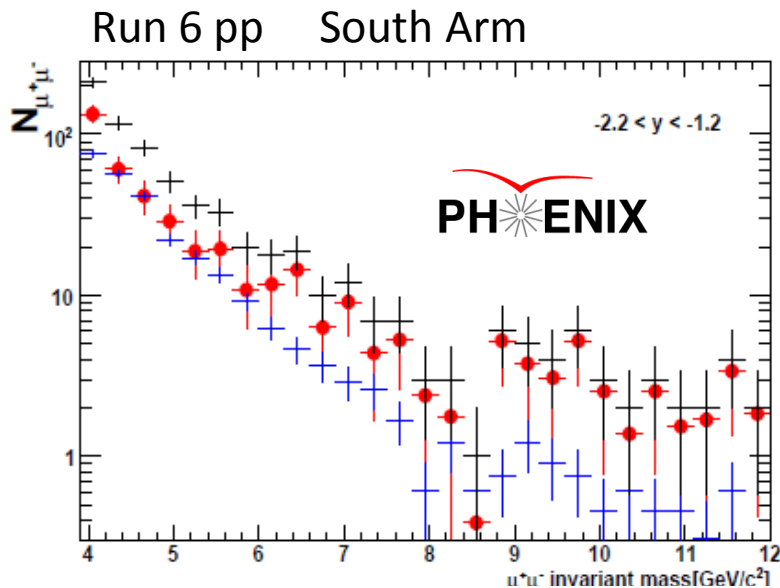
Open Bottom

CROSS SECTION MEASUREMENT

Current Results

- Run 6
 - Mid-rapidity in the di-electron channel
 - Forward and backward rapidity in the di-muon channel

Run 6 Signals



Above

Black Points: Opposite Sign Pairs

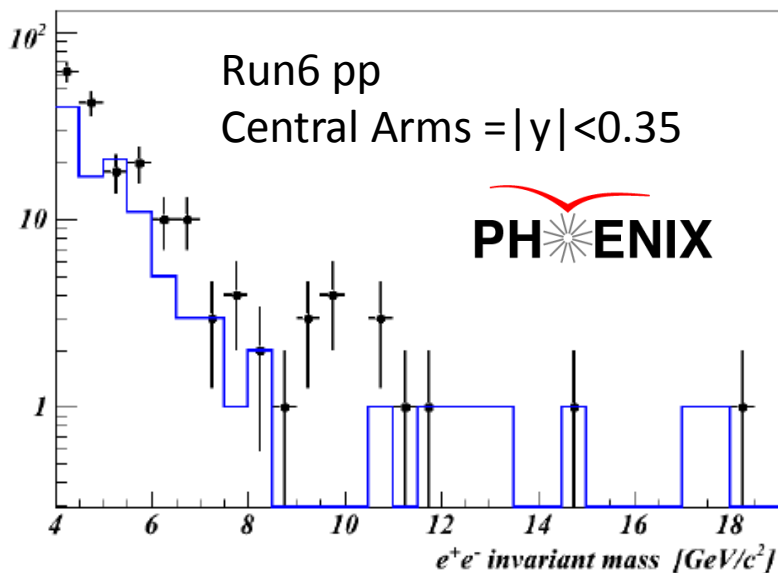
Blue Points: Same Sign Pairs

Red Points: Black - Blue

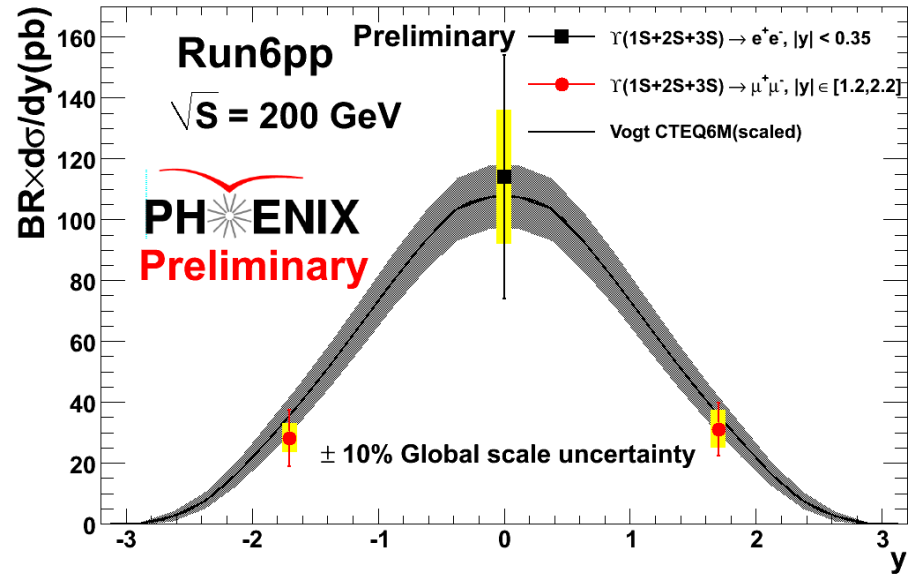
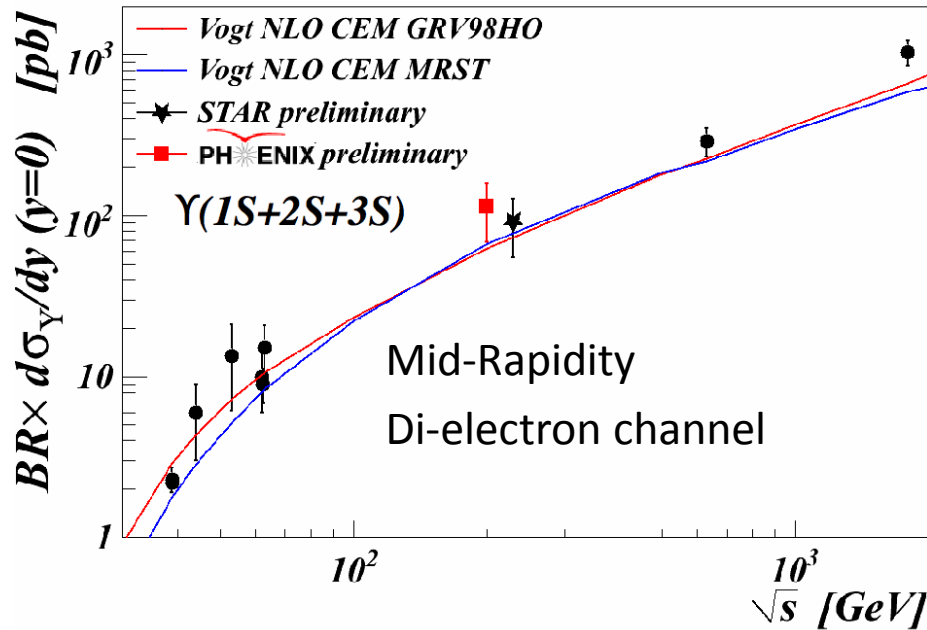
Left

Black Points: Opposite Sign Pairs

Blue Line: Same Sign Pairs



Run 6 Results



$$\left. \frac{dN}{dy} \right|_{y=0} = \frac{1}{\Delta y} \times \frac{N_{\Upsilon}}{N_{BBC}} \times \frac{(1 - f_{cont})}{\varepsilon_{BBC}^{\Upsilon} \varepsilon_{ERT} \varepsilon_A \varepsilon_{eID} \varepsilon_{mass \text{ cut}}}$$

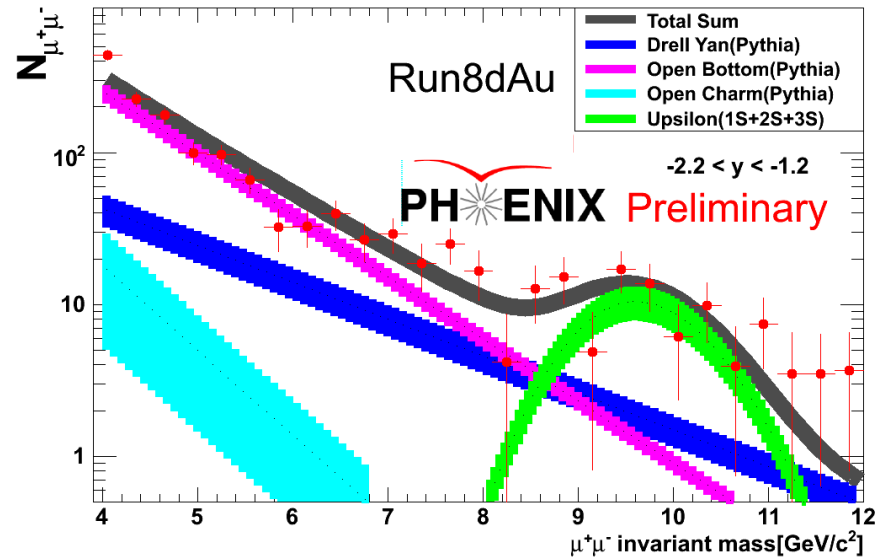
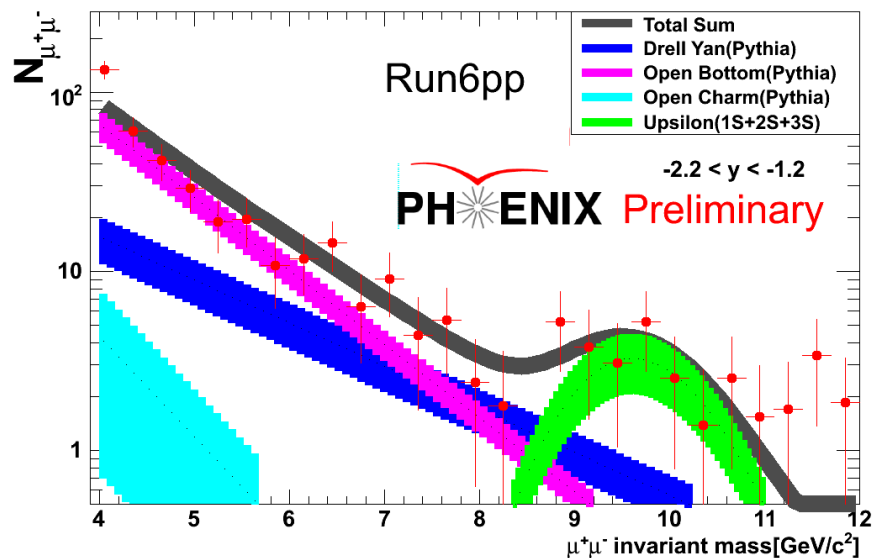
$$B\sigma_{\Upsilon}|_{y=0} = B \frac{dN}{dy} \times \sigma_{pp} \times \varepsilon_{BBCLL1}$$

NUCLEAR MODIFICATION: R_{dA}

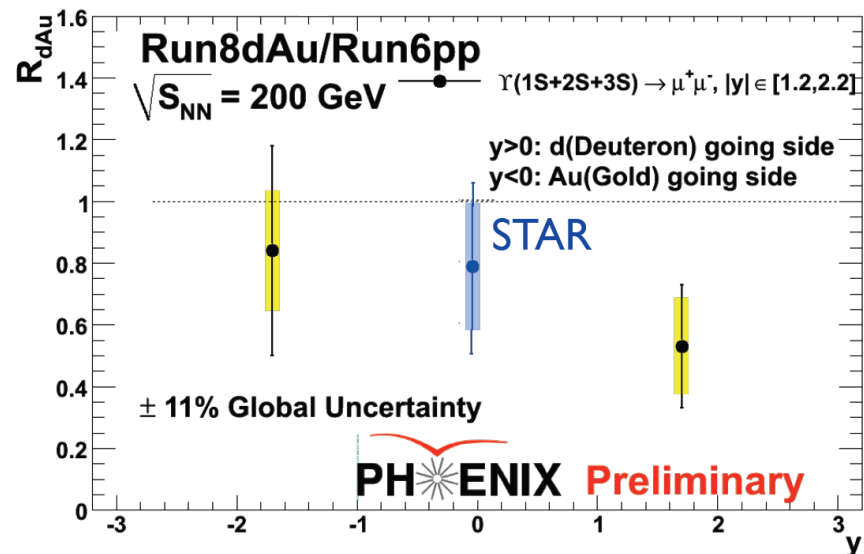
Current Results

- Use PHENIX p+p data as baseline
- Compare to calculated cross section from Run-8 d+Au to determine R_{dA}
 - Currently have result from muon arms
 - Work is being done on a mid-rapidity measurement in the Central Arms

R_{dA} Result

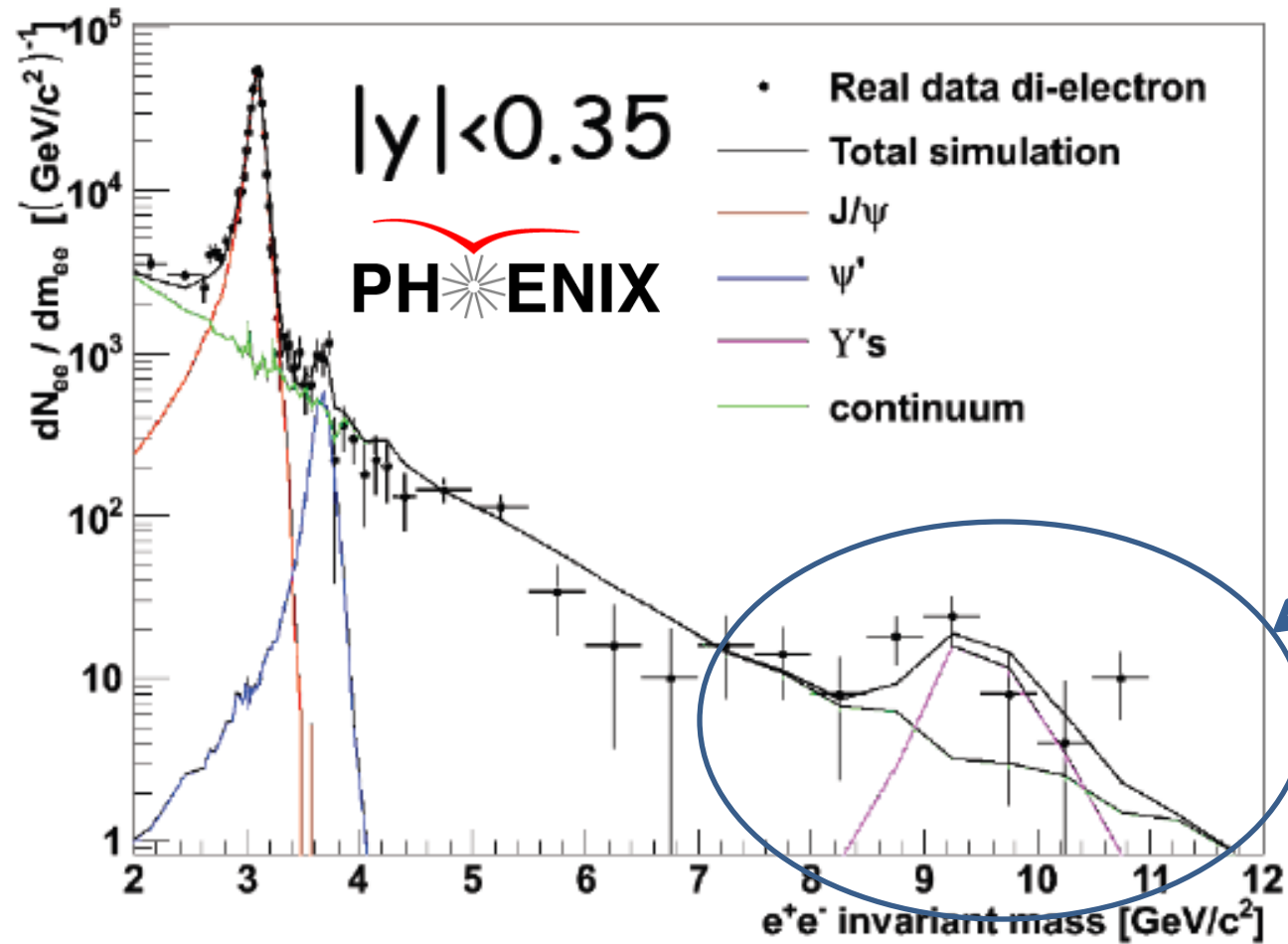


$$R_{dAu} = \frac{dN_{dAu}^r/dy}{\langle N_{coll} \rangle dN_{pp}^r/dy}$$



UPCOMING RESULTS

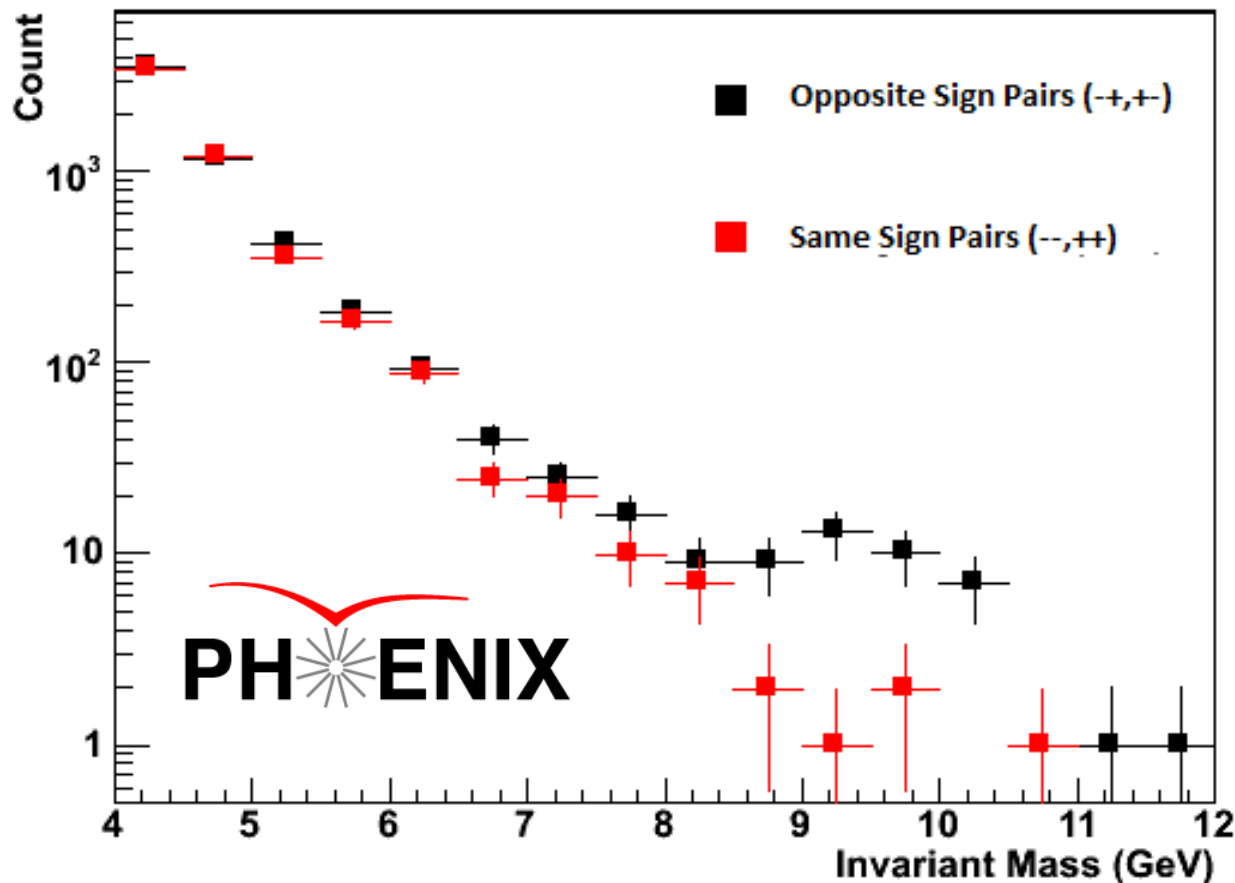
Υ at Mid-Rapidity in d+Au



Υ signal in d+Au data
at mid rapidity

Υ at Mid-Rapidity in Au+Au

Invariant Mass Spectra in the Region[4,12GeV]



An excess can be seen in the e^+e^- channel at mid-rapidity from the central arm data.

Work is still underway calculating R_{AA} , for details see my poster.

Summary

- Measured Υ cross-section in Run-6 p+p
- Measured R_{dA} at forward and backward rapidity from Run-8
- Working on R_{dA} at mid-rapidity in the di-electron channel from Run-8
- Working on R_{AA} from Run-10 for all of the PHENIX acceptance

BACKUP

P(s) Derivation(1)

$$(1) P(m)|_{\mu} = \frac{\mu^m e^{-\mu}}{m!}$$

Assume the number of counts is Poisson distribution with expectation value μ and observed counts m . The distribution is identical if you observe a number of counts and want to know the probability of an expectation value.

$$(2) P(n, \mu_f, m, \mu_b) = \frac{\mu_f^n \mu_b^m e^{-\mu_f} e^{-\mu_b}}{n! m!}$$

The probability of n foreground counts and m background counts given the two are measured independently can be written as the product of the two separate distribution.

Changing variables

$$s = \mu_f - \mu_b, \mu = \mu_b, \text{ with Jacobean } ds d\mu = d\mu_f d\mu_b$$

$$(2) \rightarrow (3) \quad P(s, \mu)|_{m,n} = \frac{\mu^m}{m!} \frac{\mu^n}{n!} e^{-2\mu} \left(1 + \frac{s}{\mu}\right)^n e^{-s}$$

P(s) Derivation(2)

$$(3) \quad P(s, \mu)|_{m,n} = \frac{\mu^m}{m!} \frac{\mu^n}{n!} e^{-2\mu} \left(1 + \frac{s}{\mu}\right)^n e^{-s}$$

Expanding $\left(1 + \frac{s}{\mu}\right)^n$ as sum $\left(1 + \frac{s}{\mu}\right)^n = \sum_{k=0}^n \frac{n!}{(n-k)!k!} \left(\frac{s}{\mu}\right)^k$

Results in (4)
$$P(s, \mu)|_{m,n} = \sum_{k=0}^n \frac{\mu^{m+n-k} e^{-2\mu}}{m!(n-k)!} \frac{s^k e^{-s}}{k!}$$

Integrating (4) over μ and recognizing it has the same form as a Gamma distribution with $b=2$ and $p-1 = m+n-k$ gives the final result

$$P(s)|_{m,n} = \sum_{k=0}^n \frac{(m+n-k)!}{m!(n-k)!} \frac{1}{2} \left(\frac{1}{2}\right)^{m+n-k} \frac{s^k e^{-s}}{k!}$$

Calculation done by M. Tannenbaum